Review of Expert Report of R.J. Lee

Submitted by Gregory P. Meeker, USGS

I have reviewed the Expert Report submitted by R. J. Lee in the matter of the United States vs. W.R. Grace and provide the following comments related specifically to issues concerning geology, mineralogy, and analytical techniques.

Fiber Morphology

Repeatedly throughout his report, Dr. Lee discusses the difference between cleavage fragments and asbestos and suggests that a substantial portion of the particles counted by EPA (or it's contractors) were cleavage fragments rather than asbestos. Dr. Lee suggests that the distinction between cleavage fragments and asbestos particles is clear-cut and that cleavage fragments were included in the EPS data even though the regulations specifically forbid inclusion of these particles. I disagree with Dr. Lee's conclusions regarding EPA counting of cleavage fragments in the Libby samples for the reasons stated below.

Cleavage is a process by which minerals break along specific crystallographic planes. Amphiboles can exhibit perfect cleavage parallel to the "c" crystallographic axis and therefore can break into smaller particles, with very high aspect ratios. Amphiboles can also grow as fibers in bundles and masses. There is also a process called parting whereby long thin amphibole particles can separate from a larger amphibole particle along planes of weakness. These different processes that comminute amphiboles form a continuum with no precise boundaries or features that are easily measurable in the laboratory. From my work with the Libby amphibole, it is clear that cleavage fragments, fibers, and a complete continuum of physical forms intermediate between these two end members, that could be called partings, are present. At a microscopic level, distinguishing between these forms on single amphibole particles can be extremely difficult to impossible.

Dr. Lee cites ISO 10312 that states "The method cannot discriminate between individual fibers of the asbestos and non-asbestos analogues of the same mineral" (i.e. asbestiform particles and cleavage fragments). This statement is true, however, Dr. Lee goes on to say that ISO 10312 specifies counting of only asbestiform minerals. In fact, ISO 10312 appears to use the terms structure, fiber, and asbestos structure interchangeably (see section 9.6.1) and requires counting of *all* amphibole structures greater than 0.5 μm in length with an aspect ratio of 5:1 or greater. Although cleavage fragments and asbestiform structures are defined in ISO 10312 there are no criteria or methods specified to actually distinguish between the two for the purposes of counting. The reason for this is, most likely, that it is often impossible to do this for single structures. The problem is exacerbated when there is a continuum of structures present in the sample as is the case with the Libby material. During an analysis an analyst can look for features such as splayed ends or fiber curvature to suggest that a particle is a fiber or is asbestiform. In the absence of such features the analyst must resort to the counting rules dealing with particle size and composition as outlined by the method. In other words, it is often possible to say that a particle is asbestiform but it is usually not possible to say with certainty that a given particle that meets the size criteria is not asbestiform. The policy that should be followed for structure counting is stated very clearly in OSHA Standard 1915.1001 App B "WHEN IN DOUBT COUNT", emphasis by OSHA.

In his Expert Report Dr. Lee makes comparisons of data used by EPA in risk calculations to fiber size data from a paper by Amandus, et. al., 1987. Dr. Lee argues on the basis of this data that the physical nature of the fibers derived from the mine in Libby has somehow changed since the mine closed. It is my opinion that this conclusion is not valid. The data from Amandus et. al., 1987 was obtained from 8 air samples provided by W.R. Grace from the mill and screening plant. There is no information on how or why these samples were collected and what they actually represent. Each of these samples does represent a snapshot in time by sampling some process or event. The fibers used in the Amandus study could be totally unique and non-representative of the average fiber released from the mine over time and currently present in the environment in Libby. Even if the samples were representative of the mill and screening plant over time, which

has not been demonstrated by Dr. Lee, there were many other activities which could have introduced hazardous material into Libby including the distribution of raw material directly from the mine. Any comparison between raw and processed material, such as material coming from the mill, may not be valid (see Figures 1 and 2 in Dr. Lee's Expert Report). In addition, the data from the Amandus paper includes only fibers greater than 5 μm in length and greater than 0.45 μm in width whereas the EPA data includes fibers of all sizes. It is difficult to comment on the appearance of the Amandus and EPA data as presented by Dr. Lee because he does not go into any detail about how he selected and presented the data in his Expert Report.

Other historical data available from published reports and from W.R. Grace records (e.g. report from P. Sebastien to H.A. Eschenbach, W.R. Grace, 10 June 1983) appears to be quite similar to the present day EPA air sample data and to the size data from the bulk samples presented in my Expert Report. It is difficult to understand why the Amandus data should be different and more representative of historical fiber size distributions than other available data sets.

Mineralogy

In his Expert Report, Dr. Lee argues that the EPA did not recognize the complexity of the mineralogy of the Libby amphibole and did not take the proper steps to address that complexity in their studies. I believe the EPA has been very aware of the mineralogical complexity of the Libby amphibole since April of 2000 if not before and has developed an appropriate strategy to deal with that complexity. The mineralogy of the Libby amphibole is discussed in detail in my Expert Report submitted for these proceedings. Dr. Lee also presents a discussion of the Libby amphibole mineralogy and the Leake, et. al., 1997 classification scheme in his Expert Report. Dr. Lee fails to point out, however, that it is not possible to employ the Leake classification method with the accepted regulatory analytical methods. The analytical methods approved for regulatory analysis of asbestos fibers simply cannot distinguish between tremolite, sodic temolite, richterite and winchite. The reasons for this are outlined in my Expert Report. The procedure

adopted by EPA, that is to classify and treat the material as Libby type amphibole or Libby type asbestos, is perfectly reasonable given this unusual situation.

With regard to Dr. Lee's assertion that only a portion of the Libby amphibole is subject to regulation (page 53 of his Expert Report) I again disagree. On page 23 of his Expert Report Dr. Lee says *"The list found in step 3.6 of ISO 10312 is typical of all current TEM methods – chrysotile, crocidolite, gunerite asbestos (amosite), anthophyllite asbestos, tremolite asbestos, and actinolite asbestos. No published TEM method calls for the inclusion of non-regulated amphiboles or cleavage fragments in the asbestos count."* This is not exactly what is said in ISO 10312. The method reads as follows:

> ***3.6 Asbestos:*** *A term applied to a group of silicate minerals belonging to the serpentine and amphibole groups which have crystallized in the asbestiform habit, causing them to be easily separated into long, thin, strong fibers when crushed or processed. The chemical Service Registry Numbers of the most common asbestos varieties are: chrysotile (12001-29-5), crocidolite (12001-28-4), gunerite asbestos (amosite) (12172-73-5), anthophyllite asbestos (77536-67-5), tremolite asbestos (77536-68-6) and actinolite asbestos (77536-66-4).*

Clearly the wording *most common* recognizes the existence of other asbestiform amphiboles and nowhere in the method does it say not to count these other forms. One possible reason for this is that the authors of the document recognized that no currently acceptable regulatory method, certainly the TEM methods, can distinguish between the different amphiboles as defined by Leake, et. al., 1978. A second reason may be that none of the methods clearly define the complete chemical boundaries for the different amphiboles.

In my Expert Report I have discussed the ambiguity of mineral nomenclature in the regulatory literature. Tremolite has been the industrial (and later regulatory) name

applied to the Libby amphibole from the early 1900's until the present day (see Appendix A of my Expert Report). This is supported by numerous W.R. Grace reports and documents, an example being a 12 May, 1983 letter from H.A. Eschenbach, W.R. Grace & Company to Mr. Allan Harvey, R.T. Vanderbuilt Co. referring to the amphibole from the Libby Montana operation as "asbestiform tremolite." A second example is the report mentioned above from P. Sebastien, McGill University to H.A. Eschenbach wherein Sebastien states "*Every fiber analyzed by EDSX* [EDS] *has yielded a spectrum similar to that shown in Figure 8. Elements identified were Na, Mg, Si, K, Ca, Fe. General features of the spectra were compatible with a mineral of the tremolite-actinolite series.*" These documents were written five years after the first International Mineralogical Association, Committee on Amphibole Nomenclature proposal to classify amphiboles of the composition found in Libby as winchite and richterite (Leake, et. al, 1978). Published, peer reviewed papers such as Amandus et. al., 1987 and Langer, et. al., 1974 also refer to the Libby asbestos as tremolite. Although the academic mineralogical names for many of the amphiboles have changed over the years, as outlined in Dr. Lee's Expert Report, the industrial and regulatory names have not.

Analytical Issues

In his Expert Report, Dr. Lee implies that much of the EDS spectral data submitted by EPA's contract laboratories is incorrectly interpreted or is improperly collected so as to render it unusable. In support on this argument Dr. Lee provides three EDS spectra (Figures 6, 7 and 8 in his report). The spectrum presented by Dr. Lee in Figure 6 of his report shows sample peaks for Mg, Si, S, Ca, and Fe. Dr. Lee argues that this is a spectrum of amosite plus gypsum and that the data was misinterpreted by the EPA contract laboratory as Libby amphibole. Gypsum is a common alteration mineral in Ca-rich, weathered rocks such as those found at the Libby mine site. It is quite possible that the spectrum is gypsum and an amphibole. This would be consistent with an asbestos fiber with adhering particles of gypsum. It is also possible that the spectrum is tremolite with an inclusion or adhering particle of iron sulfide or sulfate. The Libby amphiboles contain a significant amount of altered pyrite as shown in Figure 2 of my Expert Report.

There is no way to determine the true origin of the sulfur peak without going back to the original sample and reanalyzing the particle. I disagree with Dr. Lee that this spectrum is inconsistent with Libby amphibole. Dr. Lee also argues that the spectra shown in Figures 7 and 8 of his Expert Report were acquired under overload count conditions and implies that this renders them unusable for identification. I find no fault with the appearance of these spectra and see no reason to suspect that they were acquired at overload count rates. Even if the spectra were acquired with higher than normal count rates, the peaks are in the correct positions and the spectra are perfectly usable for identification of the elements present. On page two of his Expert Report Dr. Lee states that the EPA biased exposure estimates by "misidentification of vermiculite, talc, and mica as asbestos", he presents no evidence for this in his report.

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Date